

The Shoot Apex and Leaf Growth





Anthur H. K. O Etne



The Shoot Apex and Leaf Growth

A Study in Quantitative Biology

R. F. WILLIAMS

Division of Plant Industry C.S.I.R.O., Canberra

CAMBRIDGE UNIVERSITY PRESS



CAMBRIDGE UNIVERSITY PRESS

Cambridge, New York, Melbourne, Madrid, Cape Town, Singapore, São Paulo, Delhi

Cambridge University Press
The Edinburgh Building, Cambridge CB2 8RU, UK

Published in the United States of America by Cambridge University Press, New York

www.cambridge.org

Information on this title: www.cambridge.org/9780521112871

© Cambridge University Press 1975

This publication is in copyright. Subject to statutory exception and to the provisions of relevant collective licensing agreements, no reproduction of any part may take place without the written permission of Cambridge University Press.

First published 1975
This digitally printed version 2009

A catalogue record for this publication is available from the British Library

Library of Congress Catalogue Card Number: 74-21716

ISBN 978-0-521-20453-8 hardback ISBN 978-0-521-11287-1 paperback



Contents

Acknowledgements		page vii
1	Introductory	1
2	The quantitative description of growth	9
3	Phyllotaxis	27
	3.1 Spiral and other systems of phyllotaxis	28
	3.2 The parameters of phyllotaxis	35
	3.3 The Fibonacci angle – irrational or inevitable?	42
4	Shoot-apical systems	56
	4.1 Flax, Linum usitatissimum L.	56
	4.2 Tobacco, Nicotiana tabacum L.	81
	4.3 Cauliflower, Brassica oleracea L.	91
	4.4 Blue lupin, Lupinus angustifolius L.	97
	4.5 Subterranean clover, Trifolium subterraneum L.	100
	4.6 Eucalyptus, Eucalyptus grandis Hill and Maiden, and Eucalyptus bicostata Maiden, Blakely and Simmonds	116
	4.7 Wheat, Triticum aestivum L.	131
	4.8 Fig, Ficus elastica Roxb. ex Hornem.	146
	4.9 Yellow serradella, Ornithopus compressus L. Dianella sp. (Liliaceae)	157
	Narrow-leaf wattle, Acacia mucronata Willd. ex H. Wendl Sunflower, Helianthus annuus L.	
5	The dynamics of leaf growth	163
	5.1 Subterranean clover	163
	5.2 Wheat	172
	5.3 Relative rates of change, R and G	177
6	The growth of an inflorescence	183
7	The growth of wheat tillers	199
8	Plant growth as integration	207
	8.1 Physical constraint as a determinant of growth rate	207
		v



Contents

8.2 Constraint and the genesis of form	page 212
8.3 Organization of the shoot apex	214
Appendix	223
A.1 Three-dimensional reconstruction	223
A.2 Volume estimation by serial reconstruction	227
A.3 Phyllotaxis	230
A.4 Age equivalence and covariance	236
A.5 Data processing and presentation	239
A.6 Cell counting	243
A.7 Conversion table	244
References	245
Indexes	251



Acknowledgements

The author is happy to record his indebtedness to immediate colleagues of the Division of Plant Industry, and to others who have contributed in many ways to the preparation of this book. My personal assistant Miss R. A. Metcalf is especially deserving of my thanks, not only for dedicated technical assistance over the last five years, but for the preparation of nearly all the text figures in this volume. Her predecessor, too, Mrs T. C. Wallace is deserving of my warmest thanks. My colleague, Dr A. H. G. C. Rijven, ever my sternest critic, has helped more than he is aware by his unfailing enthusiasm and interest. He and Professor F. L. Milthorpe made many valued suggestions for the improvement of the text.

In matters mathematical and statistical I owe much to Mr G. A. McIntyre, and more recently to Mr W. J. Muller of the Division of Mathematical Statistics. They do not necessarily concur in all the procedures that have been adopted by the author.

Mr C. J. Totterdell and Mr H. G. Baas Becking, leaders of the Photography and Illustration Sections of the Division have been generous with help and advice, and Mrs A. J. Simpson and Mr E. Brunoro have done all the routine photography relating to the text figures, both half-tone and line drawings. In particular, Mrs S. C. McIntosh and Mrs Joan Simpson are warmly thanked for the dust cover design.

Mrs V. J. Ronning and several members of the Divisional Typing Pool have been very patient with my reiterated requests for typing, and I thank them.

Miss Fumei Lin was involved for a time, as a post-graduate student, in the study of *Eucalyptus* seedling growth. I acknowledge her work and regret that she was unable to complete it under my guidance.

I am especially grateful to the Australian journals of scientific research for permission to reproduce seven plates and 38 text figures previously published by them. They are specifically acknowledged in the legends and References. A few other diagrams have been modified from the originals in the literature, and due acknowledgement is made.

In conclusion, I wish to thank my wife, Ethel, for her forbearance and support throughout the project.

vii